REMARKS

Applicants respectfully request reconsideration of the Office Action mailed April 30, 2004. Claims 1-3, 6-8 and 14 are presented for examination. Claims 1, 6 and 7 have been amended, and Claim 14 has been added.

The claim amendments and new claim presented herein are fully supported by the specification as originally filed. Specifically, the amendment to Claims 1, 6 and 7 is supported by the specification at page 4, lines 16-20, wherein it is disclosed that the initial oxynitride layer has a nitrogen concentration or dosage in the range of about 6.0×10^{14} to 1.0×10^{15} atoms/cm^2. A layer having this nitrogen concentration would be recognized by any person skilled in the art as a "heavily nitrided" layer. New Claim 14 is also supported at page 4, lines 16-18. No new matter has been added.

Applicants note with appreciation the withdrawal of the finality of the previous Office Action and the reopening of prosecution on the merits. Applicants also note that a Supplemental Information Disclosure Statement (IDS) was filed on July 8, 2003, but receipt of this Supplemental IDS has not been acknowledged, and this Supplemental IDS has not been made of record in the application. Applicants respectfully request consideration of the Supplemental IDS previously filed on July 8, 2003. For the convenience of the Examiner, a copy of this Supplemental IDS is submitted herewith.

Rejection of Claim 1 under 35 U.S.C. 103(a) over Kraft et al.

Claim 1 is rejected under 35 U.S.C. 103(a) as being unpatentable over U.S. Patent No. 6,136,654 to Kraft et al. Applicants respectfully traverse this rejection.

Claim 1 is directed to a method for forming a gate dielectric for an integrated circuit device. The method comprises the steps of: (a) forming an initial heavily nitrided oxynitride layer upon a substrate material, the initial heavily nitrided oxynitride layer having an initial physical thickness; and (b) subjecting the initial heavily

nitrided oxynitride layer to a plasma nitridation, the plasma nitridation resulting in a final oxynitride layer having a final physical thickness. Thus, it is a feature of the present invention that the initial oxynitride layer is a heavily nitrided oxynitride layer, and it is a further feature that the final oxynitride layer has both an equivalent oxide thickness (EOT) of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Applicants respectfully submit that this combination of features is neither disclosed nor suggested by Kraft et al. as detailed below.

The Kraft et al. patent is directed to a method of forming thin nitride or oxynitride gate dielectrics. The method comprises the following steps: (a) forming an oxygen-containing layer on a substrate; and (b) subjecting the oxygen-containing layer to a nitrogen-containing plasma so that the nitrogen is either incorporated into the oxygen-containing layer or forms a nitride layer at the surface of the substrate (col. 2, lines 39-43). Kraft et al. disclose that the initial oxygen-containing layer may be an oxide layer, an oxynitride layer, or other insulating layer (col. 3, lines 53-54). Kraft et al., however, fail to disclose or suggest that the initial oxygen-containing layer should be a heavily nitrided layer, for the following reasons.

Kraft et al. specifically disclose that the oxygen-containing layer is "preferably either an oxide layer, an oxynitride layer, or other insulating layer" and more preferably an oxide layer (col. 3, lines 53-56). In every embodiment of Kraft et al., an oxide layer is disclosed as the initial layer. Thus, Kraft et al. teach that an oxide layer is more preferable than an oxynitride layer as the initial layer, and therefore <u>teach away</u> from using a heavily nitrided oxynitride layer as the initial layer.

Moreover, Kraft et al. fail to disclose or even suggest that the final layer, after being subjected to a nitrogen-containing plasma, has both an EOT of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. It is well known in the art that when an oxide-containing layer is subjected to a nitrogen-containing plasma, as taught by Kraft et al., such that the final gate dielectric has a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2, the resulting gate dielectric will have an EOT of greater than 15 Å. To achieve an EOT of less than 15 Å, after subjecting an

oxide-containing layer to a nitrogen-containing plasma using methods known in the art, the final gate dielectric will have a much lower nitrogen concentration. Prior to the present invention, an oxynitride gate dielectric having both an EOT of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2 had not been achieved in the art.

Applicants have surprisingly discovered that when the initial layer is a heavily nitrided oxynitride layer, a final oxynitride layer is produced which has a substantially decreased EOT without compromising the high nitrogen concentration in the dielectric. Kraft et al. fail to recognize the superiority of using a heavily nitrided oxynitride layer as the initial layer, and therefore fail to suggest that the final oxynitride layer has both an EOT of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Moreover, by teaching that it is more preferred to use oxide as the initial layer rather than oxynitride, Kraft et al. are actually teaching away from achieving the above EOT and nitrogen concentration in the final layer.

It is alleged in the final Office Action that Kraft et al. teach in Figure 7 a final oxynitride layer having both an EOT of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Applicants respectfully disagree.

Figure 7 of the Kraft et al. patent is a graph illustrating the level of oxygen and nitrogen in a gate dielectric film formed using the method of the Kraft et al. invention. The patent discloses that Figure 7 illustrates data taken from a SIMS analysis of "a 35 oxide film" nitrided under specified conditions (col. 5, lines 45-48). It is apparent from this disclosure that the phrase "a 35 oxide film" was intended to mean "a 35 angstrom oxide film" for the following reasons.

First, the units of measure on the x-axis of the Figure 7 graph are "angstroms." Figure 7 illustrates nitrogen and oxygen concentration as a function of depth in the gate dielectric film, where depth is indicated in angstroms. Moreover, in the discussion of Figure 7, it is stated that Figure 7 shows a substantially complete formation of silicon nitride (col. 5, lines 52-54). It is well known that a relatively strong concentration of nitrogen (2.0×10^{15} atoms/cm^2 or greater) introduced into an oxide

layer by plasma nitridation causes additional growth of the layer. Thus, if a 35 Å oxide film was heavily nitrided under the conditions disclosed in the Kraft et al. patent, such that substantially complete formation of silicon nitride results, one skilled in the art would expect the final thickness of the nitrided film to be far greater than 35 Å. Figure 7 supports this expectation by showing that the nitrogen concentration in the nitrided film was measured to a depth of over 50 Å. The final thickness of the film therefore must be far greater than 35 Å, which supports a conclusion that the initial oxide film thickness was 35 Å. (See Declaration of Mukesh Khare, submitted October 8, 2002, for further support of this conclusion.)

Furthermore, it is apparent from the prosecution history for the Kraft et al. patent that Figure 7 illustrates data taken from a SIMS analysis of "a 35 Å oxide film" nitrided under specified conditions. The angstrom symbol (Å) was added by Kraft et al. to the specification in the Amendment of April 28, 2000, yet the patent was issued without the requested amendment.

Figure 7 therefore clearly discloses data for an oxide film which had an initial thickness of 35 Å, and which was nitrided under conditions causing substantially complete formation of silicon nitride, resulting in a final thickness of over 50 Å. The EOT of the final nitrided film in Figure 7 therefore can not be less than 15 Å. For this reason, Applicants therefore respectfully disagree with the statement in the Office Action that Figure 7 discloses a nitrided film having an EOT of less than 15 Å.

Even if Figure 7 of Kraft et al. could be read to disclose a nitrided film having both an EOT of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2, Applicants still maintain that Kraft et al. fail to disclose or suggest, and actually teach away from using a heavily nitrided oxynitride layer as the initial layer.

For this reason, Applicants respectfully submit that Claim 1 is patentable over Kraft et al. Applicants therefore request withdrawal of this rejection.

In the Office Action, Claims 2 and 3 are discussed with regard to the Kraft et al. patent. Yet, these claims are not rejected over Kraft et al., or on any other

grounds. Applicants note that Claims 2 and 3 include all the limitations of Claim 1, and therefore are also patentable over Kraft et al. for the reasons stated above.

Claim 2 is patentable over Kraft et al. for the following additional reason. It is a feature of Claim 2 that the final thickness exceeds the initial thickness by less than 5 Å. Applicants respectfully submit that this feature also is neither disclosed nor suggested by Kraft et al.

The present invention is directed to a method for improved plasma nitridation of ultra thin gate dielectrics in integrated circuits. Specifically, this invention addresses the need for a method which results in a higher nitrogen concentration or dosage in the dielectric, yet does not substantially increase the dielectric thickness or sacrifice the uniformity of film thickness.

Prior to the present invention, it was known that nitrogen doping of silicon oxide dielectric material, particularly by Remote Plasma Nitridation (RPN), increases the dielectric constant of the material. An increased dielectric constant in gate dielectrics is desirable to help reduce the amount of leakage current experienced as compared to an undoped silicon oxide layer having the same capacitance.

Conventional methods of plasma nitridation, however, have several drawbacks, especially when used in conjunction with gate thicknesses of around 15 Å or less. One drawback is that a relatively strong concentration of nitrogen (2.0×10^{15} atoms/cm^2 or greater) introduced into an oxide layer (or lightly nitrided oxide layer) by RPN, while desirable for the purpose of reducing leakage current, causes an additional growth of the layer. For example, Figure 7 of Kraft et al. discloses data for an oxide film which had an initial thickness of 35 Å, and which was nitrided under conditions resulting in substantially complete formation of silicon nitride, resulting in a final thickness of over 50 Å. This additional growth of 15 Å is highly undesirable in ULSI integrated circuits.

Applicants have surprisingly discovered that when the initial layer is a heavily nitrided oxynitride layer instead of a silicon oxide layer (or a lightly nitrided oxide layer), a final oxynitride layer is produced which has a substantially decreased

growth in thickness without compromising the high nitrogen concentration in the dielectric. Specifically, using the method of the present invention, a final oxynitride layer having the following characteristics can be achieved: nitrogen concentration or dosage of at least 2.0×10^{15} atoms/cm^2 and a final thickness which exceeds the initial thickness by less than 5 Å. Applicants respectfully submit that this feature is neither disclosed nor suggested by Kraft et al., and therefore submit that Claim 2 is patentable over Kraft et al.

Rejection of Claims 6 and 8 under 35 U.S.C. 103(a) over Kraft et al. in view of Ito et al.

Claims 6 and 8 are rejected under 35 U.S.C. 103(a) as being unpatentable over Kraft et al. in view of U.S. Patent No. 4,980,307 to Ito et al. Applicants respectfully traverse this rejection.

Claims 6 and 8 each depend from Claim 1. As discussed previously, it is a feature of the invention defined by Claim 1 that the initial oxynitride layer is a heavily nitrided oxynitride layer, and it is a further feature that the final oxynitride layer has both an EOT of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Applicants respectfully submit that this combination of features is neither disclosed nor suggested by Kraft et al. in view of Ito et al.

As discussed previously, Kraft et al. fail to disclose or suggest, and actually teach away from, a method wherein the initial oxynitride layer is a heavily nitrided oxynitride layer. Moreover, Kraft et al. fail to disclose or even suggest a final oxynitride having both an EOT of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Ito et al. fail to remedy the deficiencies of Kraft et al. in this regard.

The Ito et al. patent is directed to a process for producing an oxynitride insulative film. The insulative film is formed by nitridation of an oxide film under a nitridation atmosphere containing nitrogen atoms (col. 4, lines 46-49). In all embodiments of Ito et al., the initial layer is an oxide. Ito et al. therefore fail to disclose or even suggest any initial oxynitride layer, whether heavily nitrided or not. Moreover,

Ito et al. fail to disclose or even suggest subjecting an oxynitride film to a plasma nitridation, and fail to disclose or suggest a final insulative film having an EOT of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Ito et al. therefore fail to provide any motivation to modify the teaching of Kraft et al. in this regard.

Accordingly, Applicants respectfully submit that Claims 6 and 8, which include all of the limitations of Claim 1, are patentable over Kraft et al. in view of Ito et al. Applicants therefore respectfully request withdrawal of this rejection.

Claim 8 is patentable over Kraft et al. in view of Ito et al. for the following additional reason. It is a feature of the invention defined by Claim 8 that the final oxynitride layer has a reduction in effective electron mobility, μ_{eff}, of less than 20% from the effective electron mobility of the initial oxynitride layer. Applicants respectfully submit that this feature is also neither disclosed nor suggested by Kraft et al. in view of Ito et al.

Kraft et al. fail to disclose or suggest anything about the effective electron mobility of their final layer with respect to their initial oxide layer. Since Kraft et al. fail to disclose or suggest that the final oxynitride layer has both an EOT of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2, Kraft et al. also fail to suggest a final layer having the additional characteristic of a reduction in effective electron mobility, μ_{eff}, of less than 20% from the effective electron mobility of the initial oxynitride layer.

Ito et al. fail to remedy the deficiencies of the Kraft et al. disclosure in this regard. Since Ito et al. fail to disclose or even suggest subjecting an oxynitride film to a plasma nitridation, Ito et al. therefore also fail to suggest a final layer having the additional characteristic of a reduction in effective electron mobility, μ_{eff}, of less than 20% from the effective electron mobility of the initial oxynitride layer.

For this additional reason, Applicants respectfully submit that Claim 8 is patentable over Kraft et al. in view of Ito et al., and therefore request withdrawal of this rejection.

Rejection of Claim 7 under 35 U.S.C. 103(a) over Kraft et al. in view of Gusev et al.

Claim 7 is rejected under 35 U.S.C. 103(a) over Kraft et al. in view of Gousev et al., "Growth and Characterization of Ultrathin Nitrided Silicon Oxide Film," IBM Journal of Research and Development, Vol. 43, No. 3, 1999, pp. 1-22. Applicants respectfully traverse this rejection.

Claim 7 depends from Claim 1. As discussed previously, it is a feature of the invention defined by Claim 1 that the initial oxynitride layer is a heavily nitrided oxynitride layer, and it is a further feature that the final oxynitride layer has both an EOT of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Applicants respectfully submit that this combination of features is neither disclosed nor suggested by Kraft et al. in view of Gousev et al.

As discussed previously, Kraft et al. fail to disclose or suggest, and actually teach away from, a method wherein the initial oxynitride layer is a heavily nitrided oxynitride layer. Moreover, Kraft et al. fail to disclose or even suggest a final oxynitride having both an EOT of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Gousev et al. fail to remedy the deficiencies of Kraft et al. in this regard.

The Gousev et al. paper is directed to methods of forming and characterizing "ultrathin nitrided silicon oxide films." The title of this paper reveals that all oxynitride films discussed therein are formed by nitriding oxide films. In other words, the initial layer in all embodiments is an oxide layer. Gousev et al. therefore fail to disclose or even suggest that the initial layer should be an oxynitride layer, whether heavily nitrided or not. Moreover, Gousev et al. fail to disclose or suggest a final oxynitride layer having both an EOT of less than 15 Å and a nitrogen concentration of at least 2.0×10^{15} atoms/cm^2. Thus, Gousev et al. provide no motivation to modify the teaching of Kraft et al. in this regard.

Accordingly, Applicants respectfully submit that Claim 7, which includes all of the limitations of Claim 1, is patentable over Kraft et al. in view of Gousev et al. Applicants therefore respectfully request withdrawal of this rejection.

Conclusion

Applicants respectfully submit that the present application is now in condition for allowance. If the Examiner has any questions or believes further discussion will aid examination and advance prosecution of the application, a telephone call to the undersigned is invited.

No fee is believed to be due for the submission of this amendment. If any fees are required, however, the Commissioner is authorized to charge such fees to Deposit Account No. 09-0458.

Respectfully Submitted,

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